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# A Scheduling Optimization Model Considering No-shows for External Container Trucks

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## Abstract

**Aiming at the uncertainty of the actual arrival time of the reserved trucks, the multi-priority queuing method is used to schedule the arrival of the trucks arriving in real time again. Entering the port: Classify the no-show container trucks that have been deployed into the second category, and can enter the port with the second priority. A model with the goal of minimizing the cost of changing truck reservations and the cost of port queuing is established, and a heuristic algorithm for real-time scheduling is designed to solve the problem, so as to update the outbound truck entry plan in different cases of no-show. Strive to help the port side to make real-time deployment of no-show container trucks in case of no-appointment for collection trucks, reduce terminal losses and reduce waiting for collection trucks. The calculation results of the example show that the method can effectively reduce the congestion cost caused by missed appointments and increase the flexibility of the reservation system.**

## Keywords

**Container Terminal; No-show; Scheduling; Heuristic Algorithm.**

## 1. Introduction

The evolving global economy creates many opportunities and presents new challenges for global supply chains and logistics operations. Despite the drop in global trade caused by the covid-19 global pandemic, overall flows were not significantly affected. The port, as the hub of import and export trade, is the transit point of international trade, and its performance is usually evaluated using two main indicators: ship berthing time and truck turnaround time [1]. Both metrics are significantly affected by the movement of trucks in and out of the container terminal. In order to further improve the efficiency of port operation, at this stage, domestic ports headed by the above port are striving to build smart ports. The "smart port" mainly seeks breakthroughs in artificial intelligence, big data applications and smart operations, and contributes to the development of my country's port technology and industry [2]. Container truck booking systems have become a common technical solution to improve port efficiency when expensive port expansions cannot meet growing demand.

In the previous research on reservation optimization, BELAQIZ S [3] established a model based on a non-stationary M(t)/Ek/c(t) queuing system in order to alleviate the congestion at the gate of the container terminal, and estimated it using the one-way fluid approximation method. The queue length of container trucks quantifies the waiting time of trucks; Li Na [4] designed a heuristic algorithm for quota optimization according to the berthing and departure requirements of export ships, aiming at the shortest waiting time of container trucks in the yard. Xu Haotian [5] considered the yard crane resource allocation plan formulated by the terminal in the process of researching container truck reservation, optimized the reservation share, reduced the congestion of the terminal, and improved the utilization rate of terminal resources; Im H et al. [6] innovatively proposed a The form of appointment collection for the cooperation between transportation companies and terminal operators;

Z.F.Guo [7] used a two-level queuing network to describe the queuing process of container trucks at the gate and the yard. Considering the interests of both the container truck fleet and the terminal, determine each Assembling time window and reservation share of arriving ships. Q.L.Xu [8] transformed the practical problem of reducing the arrival peak period of trucks into a mathematical problem with the smallest change in the arrival of trucks in each period, and finally made the arrival of container trucks relatively stable. The above studies are all traditional static reservation STAS problems.

However, due to reasons such as traffic, weather or human beings, there are often no-shows when booking container trucks. In order to improve the flexibility of the reservation system, G.Chen [9] proposed the concept of DTAS dynamic reservation system, which can estimate the waiting time in real time according to the existing reservations and help truck drivers make reservations; X.Y.Liu [10] considered the morning and evening Based on the appointment change cost, crowded queue cost and idle emission cost during peak hours, a multi-constraint scheduling model was established, and it was pointed out that the construction of a truck appointment scheduling model in an uncertain environment has become a new development direction; Ahmed M [11] used the developed truck reservation scheduling model to reduce the cost caused by the deviation between reservation and reservation time, and solve the time delay problem caused by truck arrival delay; Yin Yandong[12] When the problem of container space allocation at the exit of the lower yard occurs, the normal distribution probability method is used to approximate the actual arrival information of container trucks with different levels of no-show, and the mathematical model is optimized to minimize the number of overturned containers and the moving distance of the yard bridge. In addition, CABALLINI C[13] conducted experiments with a real case of a container terminal in Italy and Mexico, and proved the effectiveness of using a comprehensive data mining method to optimize the operation of container trucks in a container terminal. The above innovative solutions introduce dynamic factors, which can effectively reduce the extra cost caused by the missed contract.

In the optimization of pickup reservations, the queuing theory method is the key to quantify the waiting time of pickups. At this stage, the research on the arrival of trucks at the port satisfies the principle of first-come, first-served service, but the actual operation situation is complicated and changeable, such as: individual export containers need to be urgently loaded but still have to wait in line, and the non-reservation container trucks and the reserved container trucks are processed in no particular order. Wait. In the sorting of express transfer stations, M.Y.Deng[14] established a comprehensive queuing multi-objective model considering the different priorities of expedited express and ordinary express, and the results proved that this method is beneficial to the real-time scheduling of sorting machines. In the wireless communication network research, D.Wu[15] innovatively proposed a multi-priority data packet queuing delay calculation method, which increased the matching degree between the wireless network and data packets. It can be seen that the introduction of multi-priority queuing theory may become a new breakthrough point in the optimization of container truck reservations.

In this paper, in view of the uncertainty of the actual arrival time of the reserved container trucks, the multi-priority queuing method is used to plan the re-entry of the container trucks arriving in real time. The model of the target is designed, and a real-time scheduling heuristic algorithm is designed to solve it. Strive to help the port side to make real-time deployment of the no-show container trucks when the container trucks are missed, and reduce the loss of the terminal.

## 2. Problem Description

The section headings are in boldface capital and lowercase letters. Second level headings are typed as part of the succeeding paragraph (like the subsection heading of this paragraph). All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question.

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In the container terminal reservation operation, the terminal operator sets the maximum port volume for each port collection time period according to the processing efficiency of the yard. According to the collection port information announced by the terminal, the overseas collection card company makes an online reservation for collection port and arrives at the port within the reservation time period. Container trucks entering the port mainly go through two queuing processes, the gate and the yard, as shown in Figure 1. Container trucks arrive at the gate at random, and the queuing queue follows the FCFS rules; after passing the gate, the trucks enter the designated yard to queue up, and the container trucks can only leave the port after the loading and unloading service is completed at the yard bridge. The gate system is regarded as multiple independent M/M/1 queuing processes, and the queuing process of container trucks at each yard bridge in the yard obeys the M/G/1 distribution. However, due to weather, road congestion and other reasons, the reserved container truck is often unable to arrive within the specified reservation time window. This type of collection card is called a no-show container truck. No-show container trucks are divided into two categories: late no-show trucks and early no-show container trucks. The loss of container trucks will cause resource shortage in the gate yard, other arriving container trucks will not be able to complete their operations smoothly, and even cause port congestion and shutdown.

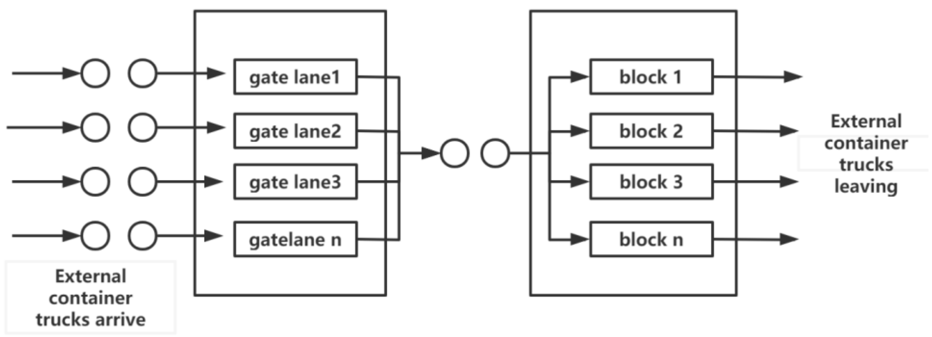


**Figure 1.** Queue of container trucks entering the port

Therefore, this chapter designs a real-time scheduling mechanism for external container trucks for no-show container trucks. Figure 2(a) shows the initial arrival of external container trucks at a container terminal within a certain period of time, with green representing on-time arrival, red representing late arrival, and blue representing early arrival. In the dispatching system, if the external container truck can report on time in the reserved time period, then the container truck is classified as a first-class container truck and can enter the gate and yard channel with priority; if this time period is not the reserved arrival time period of the container truck, the Collection trucks will be divided into queues of no-show container trucks. Only "(1) a class of container trucks can complete the task; (2) the yard has the remaining capacity to handle other tasks." When both conditions are met at the same time, the queue of no-show container trucks can be dispatched according to the urgency of the task. No-show container trucks that can enter the port during this period are classified as second-class container trucks and enter the gate and yard with the second priority to wait in line for service. No-show container trucks that are not scheduled to enter the port during this period will continue to wait for dispatch in the next period.

 

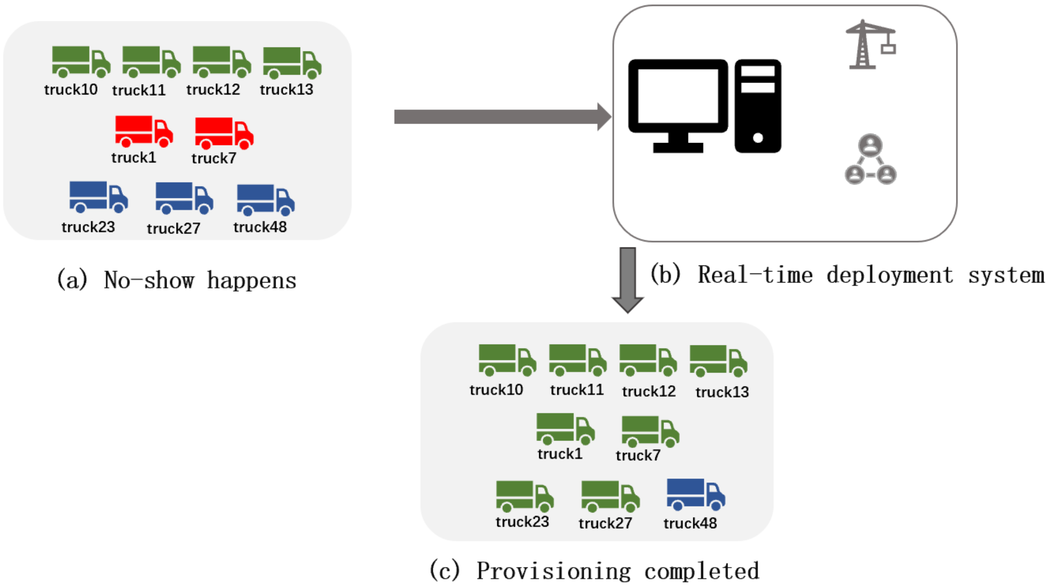


**Figure 2.** The real-time deployment process of container trucks

The scheduling process of no-show container trucks entering the port is shown in Figure 2(b). No-show container trucks should not be able to enter the port according to the appointment rules, but the actual yard still has additional remaining capacity. Through the scheduling algorithm in this chapter, the missing trucks can be scheduled to a reasonable time window to improve the flexibility of the external container truck entry system. In addition, this chapter also uses the algorithm to optimize the scheduling quota of each time period, and obtains the optimal number of container trucks that can be dispatched in each time window under different no-show conditions. After the scheduling is completed, the entry plan is shown in Figure 2(c). The purpose of this chapter is to find a suitable time window for the no-show container trucks to enter the port, reduce the appointment failure caused by uncertain factors, reduce the waiting of truck drivers and improve the utilization rate of the yard bridge.

## 3. Literature References

### 3.1 Model Assumptions

(1) During the decision-making period, the number of containers entering and leaving the port is known, and the additional yard turnover cost caused by the change of the arrival sequence of external container trucks is not considered.

(2) The model ignores the impact of internal container truck yard loading and unloading on external container trucks.

(3) Each yard container area has only one yard bridge, and the service capacity of each yard bridge is the same; the service capacity of each gate channel is also the same.

(4) Containers are all 1 TEU standard containers. By default, only 1 container can be loaded at a time when picking up and delivering the container outside the container.

(5) After making an appointment for a container truck to enter the port, only the container picking operation or the container delivery operation will be carried out, regardless of the situation of re-entry and re-exit.

(6) Ignore the travel time spent by container trucks traveling between the gate and the yard.

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(7) The rescheduled no-show container trucks can enter the port within the dispatch time window, and there is no second no-show.

### 3.2 Symbol Definition

Collection and parameters:

$\varphi$ the $\varphi_{th}$ time window, $\varphi = 1,2,...M$ ;

$t$ the $t_{th}$ time period $t = 1,2,...T$ ;

$k$ the $k_{th}$ gate lane, $k = 1,2,...K$ ;

$j$ the $j_{th}$ yard block, $j = 1,2,...J$ ;

$\delta$ Coefficient of variation of time distribution;

$C_1$ penalty cost for not arriving on time;

$C_2$ Time cost of waiting for scheduling;

$C_3$ queuing cost at the gate;

$C_4$ queuing cost at the yard;

$r_{kt}$ the time period $t$, the maximum service volume of the gate lane $k$;

$r_{jt}$ the time period $t$, the maximum service volume of the yard block $j$;

$\theta_{kt}$ time period $t$,Utilization rate of gate lane $k$;

$\theta_{jt}$ time period $t$, Utilization rate of yard crane $j$;

$x_{kt}$ time period $t$, The queue length of the external card at the gate line $k$;

$x_{jt}$ time period $t$, Queue length of external trucks at the yard block $j$;

$b_{kt}$ time period $t$, The number of external cards leaving the gate lane $k$;

$b_{jt}$ time period $t$, Number of external trucks leaving at the yard crane $j$;

$x_{n\varphi}$ the container truck $n$ is scheduled to arrive at the time window $\varphi$;

$q_{n\varphi}$ the container truck $n$ actually arrives in the time window $\varphi$, 0-1 variable;

$z'_{n\varphi}$ After adjustment, the container truck $n$ arrives in the time window $\varphi$ and is at the first priority, 0-1 variable;

$a_n$ Estimated arrival time window of container trucks $n$;

$s_n$ Actual arrival time window of container trucks $n$;

Variables:

$a_{\varphi 1}$ the number of container trucks arriving at the gate in the first category;

$a_{\varphi 2}$ the number of container trucks arriving at the gate in the second category;

$y_{\varphi 1}$ In time window $\varphi$, the number of first-class container trucks arriving at the yard;

$y_{\varphi 2}$ In time window $\varphi$, the number of first-class container trucks arriving at the yard;

$p_{n\varphi}$ No-show container truck $n$ ,the deployment arrives in the time window $\varphi$, 0-1 variable;

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$z_{n\varphi}$ After adjustment, container truck $n$ arrives in the time window $\varphi$, 0-1 variable;

$c_n$ No-show container truck $n$, time window for re-appointment;

$z_n$ the final arrival time window of the container truck $n$;

$\kappa$ The number of container trucks accepted for deployment in each time window;

Objective function:

$$minZ = C_1 \bullet \sum_n \left| z_n - a_n \right| + C_2 \bullet \sum_n \left| z_n - s_n \right| + C_3 \bullet \sum_\varphi (a_{\varphi 1} \times w_{\varphi,G} + a_{\varphi 2} \times w'_{\varphi,G}) + C_4 \bullet \sum_\varphi (y_{\varphi 1} \times w_{\varphi,Y} + y_{\varphi 2} \times w'_{\varphi,Y})$$

The objective function is to minimize the penalty cost of external container trucks, the cost of waiting for scheduling, and the total cost of queuing at gates and yards.

The number and scheduling constraints are as follows (1)-(6):

$$z_{n\varphi} = \begin{cases} x_{n\varphi} & , \ a_n = s_n \\ p_{n\varphi} & , \ \text{others} \end{cases}, \ \forall \varphi \in [1...M] \tag{1}$$

Formula (1) is the container trucks that are allowed to enter the gate within the time window, which are divided into two categories: the first category, the time window is the container truck of the reserved time window, which can directly enter the port for container delivery operations; the second category, the time window is the non-reservation time window for container trucks, but the port has remaining capacity to handle it, and the no-show container truck can still enter the port.

$$\sum_n p_{n\varphi} \le \kappa, \forall \varphi \in [1...M] \tag{2}$$

$$a_{\varphi 1} = \sum_n x_{n\varphi}, \forall \varphi \in [1...M] \tag{3}$$

$$a_{\varphi 2} = \sum_n p_{n\varphi}, \forall \varphi \in [1...M] \tag{4}$$

$$a_\varphi = \sum_n z_{n\varphi}, \forall \varphi \in [1...M] \tag{5}$$

$$\sum_n \sum_\varphi z_{n\varphi} = \sum_n \sum_\varphi x_{n\varphi} \tag{6}$$

Equation (2) is the maximum number of container trucks that can be deployed by no-show container trucks in each time window; Equations (3)-(5) are the number of first-class container trucks, the second-class container trucks and the number of each time window respectively. The total amount of container trucks arriving in the time window; Equation (6) The sum of the scheduled arrival volume and the final arrival volume remains unchanged, ensuring that all container trucks enter the port.

The first type of container truck gate queuing constraints are as follows (7)-(11):

$$a_{kt} = a_{\varphi 1} / TK \tag{7}$$

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$$x_{k,t+1} = \max\left(x_{kt} + a_{kt} - b_{kt}, 0\right), \forall t \in \left[1...T\right],\ \ k \in [1...K]; \tag{8}$$

$$b_{kt} = r_{kt} \cdot \theta_{kt}, \forall t \in \left[1...T\right],\ \ k \in [1...K]; \tag{9}$$

$$\theta_{kt} = \frac{x_{kt}}{x_{kt} + 1}, \forall t \in \left[1...T\right],\ \ k \in [1...K]; \tag{10}$$

$$w_{\varphi,G} = \frac{\sum_t \sum_k x_{kt}}{\sum_t \sum_k b_{kt}}, \forall t \in \left[1...T\right],\ \ k \in [1...K]; \tag{11}$$

Equation (7) is the number of external container trucks arriving at the gate; Equation (8) is the flow conservation transfer formula; Equation (9) is the departure amount of external container trucks in the gate passage; Equation (10) is the utilization rate of the gate lane. Equation (11) in a single time window, the average waiting time of each vehicle at the gate.

The queuing constraints of the first type of container trucks in the yard are as follows (12)-(17):

$$a_{jt} = \frac{\sum_k b_{kt}}{J} \tag{12}$$

$$y_{\varphi 1} = \sum_k \sum_t b_{kt}, \forall \varphi \in [1...M] \tag{13}$$

$$x_{j,t+1} = \max\left(x_{jt} + a_{jt} - b_{jt}, 0\right), \forall t \in \left[1...T\right],\ \ j \in [1...J]; \tag{14}$$

$$b_{jt} = r_{jt} \cdot \theta_{jt}, \forall t \in \left[1...T\right],\ \ j \in [1...J]; \tag{15}$$

$$\theta_{jt} = \frac{x_{jt} + 1 - \sqrt{x_{jt}{}^{2} + 2 \cdot \delta^{2} \cdot x_{jt} + 1}}{1 - \delta^{2}}, \forall t \in [1...T],\ \ j \in [1...J] \tag{16}$$

$$w_{\varphi,Y} = \frac{\sum_t \sum_j x_{jt}}{\sum_t \sum_j b_{jt}}, \forall t \in \left[1...T\right],\ \ j \in [1...J]; \tag{17}$$

Equation (12) is the number of container trucks arriving in each yard partition; Equation (13) is the total number of container trucks of the first type arriving at the yard in each time window; Equation (14) is the flow conservation transfer formula; Equation (15) is The amount of container trucks leaving outside the container area of the yard; Equation (16) is the utilization rate of the container area of the yard. Equation (17) in a single time window, the average waiting time of each vehicle in the yard.

The queuing constraints of the second type of container trucks at gates and yards are as follows (18)-(21):

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$$\tau_{kt} = \frac{a_{kt}}{r_{kt}}, \quad \forall t \in [1...T], \quad k \in [1...K]; \tag{18}$$

$$\tau_{jt} = \frac{a_{jt}}{r_{jt}}, \forall t \in [1...T], \quad j \in [1...J]; \tag{19}$$

$$w'_{\varphi,G} = \sum_t \sum_k (\frac{x'_{kt}}{b'_{kt}} + \frac{a_{kt}}{r_{kt}}), \forall t \in [1...T], \quad k \in [1...K]; \tag{20}$$

$$w'_{\varphi,J} = \sum_t \sum_j (\frac{x'_{jt}}{b'_{jt}} + \frac{a_{jt}}{r_{jt}}), \forall t \in [1...T], \quad j \in [1...J]; \tag{21}$$

Equation (18) is the extra waiting time of the second type of container trucks at the gate (the time required to wait for the first type of container trucks to complete the service at the gate); Equation (19) is the additional waiting time of the second type of container trucks at the yard ( (20) the average queuing time of the second type of container trucks at the gate; constraint (21) the average queuing time of the second type of container trucks in the yard. Equation (20) (21) first uses the method of calculating the queuing time of the first type of container trucks to obtain the second type of container truck gate, $x'_{kt}, b'_{kt}, \theta'_{kt}$ , $a_{kt,2} = a_{\varphi 2} / TK$ ; the second type of container truck yard, $x'_{jt}, b'_{jt}, \theta'_{jt}$ , $a_{jt,2} = \frac{\sum_k b_{kt,2}}{J}, y_{\varphi 2} = \sum_k \sum_t b_{kt,2}$ etc.; secondly, citing Wu Di [15] In this paper, a method is proposed to solve the queuing delay by arriving in batches. The second priority container truck queuing time = waiting time for the first priority container truck to complete the operation + the same second priority container truck queuing time.

## 4. Heuristic Algorithm Solution

### 4.1 Algorithm Design

Most of the ports in Shanghai, Qingdao, Ningbo and other places are large container terminals, and the daily throughput of container trucks is as high as 10,000. The exact solution method cannot obtain results in a short time. To this end, a set of heuristic algorithms needs to be designed to schedule real-time arriving container trucks.

(1) Dispatching rules for no-show container trucks

When the no-appointment container trucks are reassigned, the no-appointment set $M$ is first generated, in which formula (22) is used to sort all the no-appointment container trucks. In a single time window, if $T_n < 0$, the container truck is a late-arriving container truck; $T_n > 0$, the container truck is an early-arriving no-appointment container truck. The longer you are late, the more priority you will be assigned to the second-class container truck category and dispatched to enter the port. In addition, not all no-show container trucks can be dispatched to the port immediately, and they need to comply with the second type of container truck admission rules in the next section (2). That is, when the number of no-show container trucks allocated in a single time window and the busyness of the yard reach the specified value, they are no longer allowed to enter, and these no-show container trucks will enter the set of no-shows in the next time window.

$$T_n = P_n - Z_n \tag{22}$$

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The column "Number of Differences" in Table 1 below is T. According to the size of the T number, a "permitted entry number" was issued to the no-show container truck. The smaller the serial number, the better the priority. If no-show container trucks 23 and 27 cannot be arranged to enter the port in time window 3, they can wait until the next stage (time window 4:00), in time window 4, container trucks 23 and 27 arrive on time on time, and the first class directly takes priority Enter. Another example is the no-show container truck 48, which is not allowed to enter during time window 3. By time window 4, it still needs to enter the default set sorting, and so on, until it can enter the port.

**Table 1.** Container truck scheduling rules table

| Time window | Arrived on time container truck number | Container Truck Type | No-show Container Truck Appointment Arrival Time Window | Type of no-show | Difference quantity | Subpriority Admission Sequence Number |
|---|---|---|---|---|---|---|
| 3 | 10 | 1th | | | | |
| 3 | 11 | 1th | | | | |
| 3 | 12 | 1th | | | | |
| 3 | 13 | 1th | | | | |
| 3 | 15 | 1th | | | | |
| 3 | 17 | 1th | | | | |
| 3 | 18 | 1th | | | | |
| 3 | 19 | 1th | | | | |
| 3 | 21 | 1th | | | | |
| 3 | 22 | 1th | | | | |
| 3 | 9 | 2th | 2 | late | -1 | 2 |
| 3 | 7 | 2th | 1 | late | -2 | 1 |
| 3 | 1 | 2th | 1 | late | -2 | 1 |
| 3 | 23 | - | 4 | early | 1 | 4 |
| 3 | 27 | - | 4 | early | 1 | 4 |
| 3 | 48 | - | 5 | early | 2 | 3 |
| 3 | 34 | 2th | 5 | early | 2 | 3 |
| 4 | 23 | 1th | | | | |
| 4 | 27 | 1th | | | | |
| 4 | 30 | 1th | | | | |
| 4 | 31 | 1th | | | | |
| 4 | 48 | - | 5 | early | 1 | 2 |
| 4 | 14 | 2th | 3 | late | -1 | 1 |

(2) Access rules for the second category of container trucks

The number of no-show container trucks that can enter in a single time window is affected by two aspects: (1) the number of dispatched container trucks $\kappa$ specified by the port operator in a single time window; (2) the busyness of the yard bridge, the algorithm A busy value $w$ is set, and the second

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type of container trucks are allowed to enter only when the busyness of the on-site bridge is less than $w$.

(3) Queue rules for two types of container trucks

When multiple priority container trucks arrive at the same time, the container truck queue is divided into two columns. The first category of container trucks has priority and will enter the gate yard first. The second type of container truck needs to wait for the first type of container truck to be serviced before entering.

(4) Use the population algorithm to continuously optimize the number of scheduling

With the change of the no-appointment situation, the number of no-show container trucks $\kappa$ that can be dispatched in each time period specified by the port operator loses the meaning of regulation. Therefore, the population algorithm is used to re-optimize the allocation rate of each time period to improve the flexibility of the reservation system.

(5) Evaluation function

The objective function of the model is used as an evaluation function to evaluate the time window of the no-show container truck deployment, and the minimum solution of the objective function is selected as the optimal solution. The optimal solution gives the scheduling quantity of each time window. In addition, the time corresponding to each container truck in the optimal solution The window is the reassigned arrival time of the no-show container truck n. Because the container trucks entering the port is in a non-stationary state, this chapter still uses the PSFFA queuing theory method to judge the remaining capacity of the port and calculate the objective function value.

### 4.2 Specific Steps of Heuristic Algorithm

In this chapter, after formulating the scheduling rules, by optimizing the number of no-show container trucks that can be dispatched in each time period, the waiting time of container trucks in the port is reduced. The initial solution of the heuristic study is based on the real arrival of container trucks in a single time window. Within a single time window, the arrival of each container truck is subject to a no-show judgment. If the reservation time $P_n$ of the container truck n is the same as the actual arrival time $R_n$, it will be classified as the first type of container trucks to queue up to enter the port directly; if they are not the same , then the no-show container truck needs to be rescheduled, and the scheduled arrival time is $Z_n$.

The general steps of the algorithm are as follows:

Step 1: Initialize the particle population, set the population size, number of iterations, particle position initialization and velocity initialization, etc.

Step 2: The initial scheduling scheme generated according to the port information is used as the initial solution.

Step 3: Extract the reservation system information to determine the type of container trucks that are about to arrive at each time period. If the reservation time p of container truck n is the same as the actual arrival time $R_n$, it is classified as the first type of container truck; if the reservation time $P_n$ of container truck n is Different from the real arrival time r, it is classified as a no-show container truck and enters the no-show pool to wait for scheduling;

Step 4: Schedule and sort the no-show container trucks. The longer they are late, the higher they are sorted to prevent them from being late and delaying loading. The scheduling pool is generated from the first time window, and the scheduled no-show container trucks are divided into the second type of container truck queue. Unscheduled no-show container trucks enter the next time window to continue scheduling.

Step 5: The particle fitness value is calculated and the individual group optimal value is updated. Determine the total cost of the scheduling scheme generated by the current quota.

Step 6: Update the position and velocity of the particles.

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Step 7: Verify operation. Check whether there is an excessively high busy rate of the bridge at the current dispatch quota for entering the port.

Step 8: Return to Step 5 until the iteration reaches the specified number of times, and output the final dispatching plan $F_n$ for container trucks.

## 5. Example Analysis

In order to verify the feasibility of the model algorithm in this chapter, simulation experiments and comparative studies are carried out. This chapter uses the information of 2937 container trucks that actually entered the port on a certain day to conduct a numerical simulation. As shown in Table 2, the actual entry situation of 2937 container trucks is briefly classified. This chapter still selects the entry information of a terminal in Shanghai, and conducts the experiment under the reservation time window of 1 hour. Other input variable information is as follows: the average service efficiency of the field bridge is 0.6 vehicles per minute, and the average service efficiency of the gate is 0.7 vehicles per minute. According to the terminal data, the waiting cost of external container trucks at the gate is about 67 yuan per hour, the waiting cost in each container area of the yard is about 42 yuan per hour, the penalty cost of external container trucks is 75 yuan per hour, and the additional waiting cost is 50 yuan per hour.

**Table 2.** Actual container truck entry information

| Time window | Number of arrivals on time | Number of late arrivals | number of early arrivals |
|---|---|---|---|
| 1 | 85 | 0 | 46 |
| 2 | 50 | 3 | 20 |
| 3 | 64 | 1 | 20 |
| 4 | 57 | 4 | 23 |
| 5 | 66 | 4 | 20 |
| 6 | 83 | 8 | 20 |
| 7 | 146 | 9 | 26 |
| 8 | 135 | 10 | 30 |
| 9 | 84 | 10 | 8 |
| 10 | 61 | 12 | 13 |
| 11 | 80 | 10 | 7 |
| 12 | 57 | 7 | 12 |
| 13 | 86 | 9 | 16 |
| 14 | 121 | 10 | 14 |
| 15 | 167 | 11 | 7 |
| 16 | 130 | 16 | 13 |
| 17 | 104 | 11 | 4 |
| 18 | 71 | 16 | 8 |
| 19 | 84 | 18 | 5 |
| 20 | 107 | 17 | 5 |
| 21 | 133 | 16 | 7 |
| 22 | 172 | 20 | 1 |
| 23 | 146 | 30 | 1 |
| 24 | 48 | 22 | 0 |

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The algorithm iteration diagram is shown in Figure 3, and the algorithm iteration converges at about 120 generations. After dispatch, the average queuing time of the first type of container trucks in the port was 20.61 minutes, and the average queuing time of the second type of container trucks was 25.67 minutes.

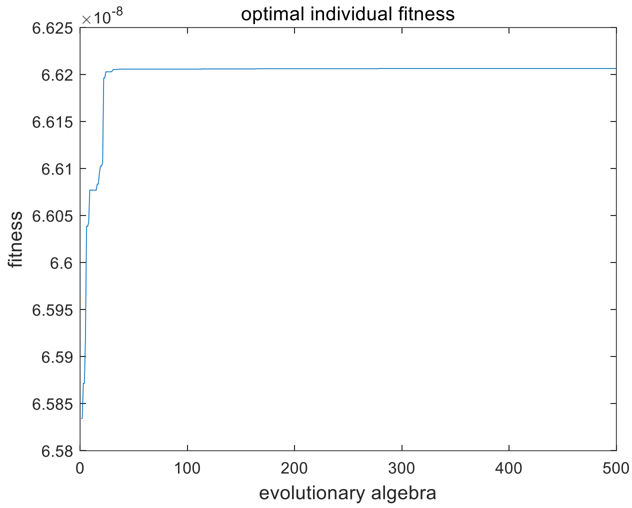


**Figure 3.** The actual arrival information of container trucks

For no-show container trucks, if the admission rules are strictly implemented according to the reservation system information, then 600 container trucks will not be able to complete the pick-up and delivery operations, which will cause huge losses to shipping companies and freight companies, which is obviously not feasible; if no-show is allowed to arrive The container trucks that arrive at the port directly enter the port and line up at the gate and the yard at the same level as the container trucks arriving on time. This is unfair. This method is collectively referred to as Strategy 2 below. If the real-time strategy 2 method is used to enter the port, the gate of the container terminal will be busy at the three time periods of 7:00, 15:00 and 22:00. Figure 4 compares the scheduling method in this chapter (hereinafter referred to as strategy 1) with the strategy 2 scheme. The number of external container trucks arriving in each time period under strategy 1 is more stable than that in strategy 2.

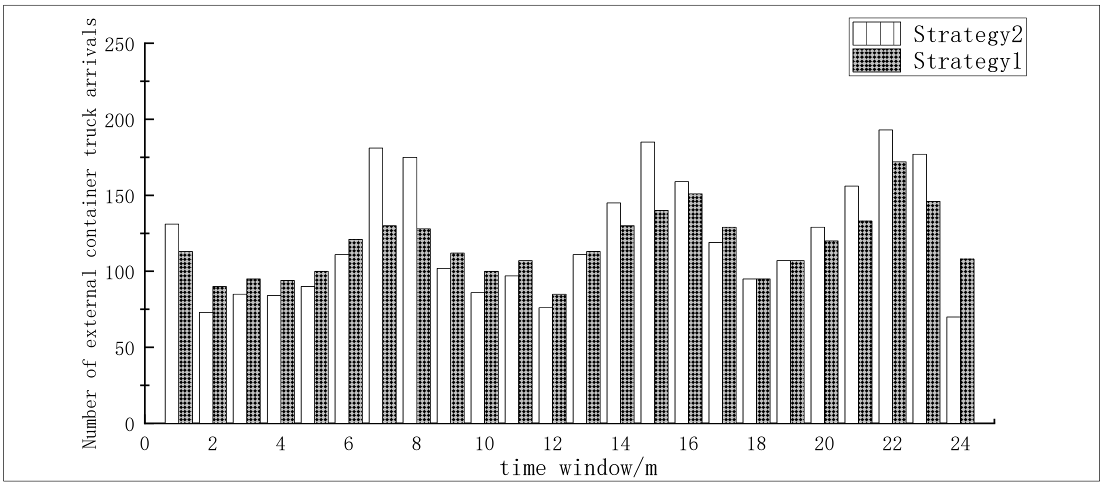


**Figure 4.** Comparison of the number of inbound ports under the two strategies

In order to verify the validity of the method in this chapter, Table 3 also lists the comparison of the waiting time of container trucks at the gate under three different no-show probabilities. Using the method of this chapter, the average waiting time of the first type of container trucks at the gate is

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significantly reduced, and the multi-priority queuing method gives sufficient priority to the first type of container trucks entering the port on time as agreed. Through the optimization of the allocation quota, although the second type of container trucks are in the sub-priority service, the total waiting time at the port has not increased significantly. In addition, it can be seen from Table 3 that the calculation speed of the improved particle swarm algorithm is significantly better than that of the traditional calculation method, and an effective solution can be obtained in a relatively short time.

**Table 3.** Average waiting time of container trucks at the gate under different no-show probabilities

| Missing Probability | The average waiting time of the first class container truck gate /min | Average waiting time at the gate of Class II container trucks /min | Average waiting time at gate without classification /min | Iteration 500 generations solve time /s | |
|---|---|---|---|---|---|
| | | | | GA | PSO |
| 0.05 | 5.020 | 6.49 | 5.674 | 3321 | 107 |
| 0.2 | 4.267 | 6.730 | 5.092 | 3607 | 180 |
| 0.4 | 4.582 | 7.34 | 6.136 | 5489 | 230 |

The article sets that when the busyness of the yard bridge in the container area is less than 80%, the container trucks that have missed the appointment can be arranged to enter the port. When the busy threshold of the yard bridge is increased, the time window scheme for no-show container trucks will decrease accordingly. When the busy threshold of the on-site bridge was set to 90%, after running the calculation example, it was found that 32 external container trucks could not be arranged to enter the port smoothly.

Table 4 shows the waiting time of various types of container trucks in the port queue under different appointment time window lengths. The shorter the length of the reservation time window, the better the scheduling optimization effect of this chapter considering multi-priority actual entry into the port. Under the method of implementing the classification of arriving container trucks, the external container trucks that arrive at the port on time can enter the port with priority to complete the operation, which is more in line with the actual rules than the single-priority queue.

**Table 4.** Queue waiting time of various container trucks at the port under different reservation lengths

| time window length /h | The average waiting time of the first type of container trucks in port /min | The average waiting time of the second type of container trucks in port /min | Average wait time without sorting /min |
|---|---|---|---|
| 0.5 | 19.37 | 23.73 | 20.46 |
| 1 | 20.61 | 25.67 | 21.58 |
| 2 | 21.37 | 27.86 | 23.01 |

## 6. Conclusion

The container terminal controls the arrival of external container trucks through the container truck reservation method, which can relieve the queue congestion inside the terminal. However, due to uncertain factors such as weather, container trucks who make reservations often fail to arrive at the port on time, and the problem of congestion inside the terminal still exists. In this chapter, in view of the uncertainty of the actual arrival time of the reserved container trucks caused by such reasons, the multi-priority queuing method is used to schedule the arrival of the container trucks arriving in real time, and strive to help the port side when the container trucks are missed. , which enables real-time

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deployment of no-show container trucks. In addition, for the real-time scheduling of no-show external container trucks, this chapter also studies the impact of the arrival of container trucks at different scales and different no-show levels on the queuing operation at the terminal, and designs a heuristic algorithm, which can obtain a satisfactory solution in a short time.

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